

### Claims

1. A method for determining a position ( $P_{xyz}(MT)$ ) of a signal transmitter (MT) comprising the steps of:

5 receiving a direct sequence spread spectrum signal ( $S_{MT}$ ) from the transmitter (MT) in each of at least three physically separated sensors (100a, 100b, 100c, 100d) whose respective positions are known, the signal ( $S_{MT}$ ) representing a set of symbols,

10 correlating, in each of the sensors (100a, 100b, 100c, 100d) a representation ( $S_{BB}$ ,  $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) with at least one local spreading sequence ( $S_{PP}$ ,  $S_{bin}$ ) to determine a respective estimated transmission delay ( $d$ ) of the received signal ( $S_{MT}$ ), the received direct sequence spread spectrum signal ( $S_{MT}$ ) having a nominal chip period ( $T_C$ ), the  
15 correlating step producing a chip level synchronization at least within an uncertainty region of one half nominal chip period ( $T_C/2$ ), and

calculating a distance ( $D_{MT-100}$ ) between the signal transmitter (MT) and each of the at least three sensors (100a, 100b,  
20 100c, 100d) based on the respective estimated transmission delays ( $d$ ), **characterized by** the correlating step comprising the further sub-steps of:

over-sampling the representation ( $S_{BB}$ ) of the received signal ( $S_{MT}$ ) within the uncertainty region to obtain a corresponding over-sampled representation of the received signal ( $\langle S_{BB} \rangle$ ),  
25 the over-sampling being equivalent to a reduced chip period ( $T_{C1}$ ) which is shorter than the nominal chip period ( $T_C$ ),

selecting a local spreading sequence ( $S_{PP}$ ) containing poly-phased symbol values which are different from the set of  
30 symbols represented by the received signal ( $S_{MT}$ ), the selected local spreading sequence ( $S_{PP}$ ) having a nominal chip period being equivalent to the reduced chip period ( $T_{C1}$ ), and

cross-correlating the over-sampled representation ( $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) with the selected local spreading  
35 sequence ( $S_{PP}$ ) to obtain an improved uncertainty region which is more limited than one half nominal chip period ( $T_C/2$ ).

2. A method according to claim 1, **characterized by**, prior to said cross-correlating sub-step, the correlating step involving an auto-correlating sub-step wherein the representation ( $S_{BB}$ ) of the received signal ( $S_{MT}$ ) is correlated with a local copy ( $S_{bin}$ ) of the transmitted spreading sequence to provide an uncertainty region of one half nominal chip period ( $T_C/2$ ) around an auto-correlation peak (501).
3. A method according to any one of claims 1 or 2, **characterized by**:
- 10 examining a phase difference function ( $\Delta\phi$ ) which describes a phase difference between neighboring samples in a cross-correlation function resulting from said cross-correlating sub-step,
- 15 detecting a position (P) in said phase difference function ( $\Delta\phi$ ) where the phase difference between neighboring samples exceeds a predetermined magnitude ( $\Delta\phi_{Th}$ ), and
- defining the improved uncertainty region adjacent to samples in the over-sampled representation of the received signal ( $\langle S_{BB} \rangle$ ) equivalent to said position (P).
- 20 4. A method according to any one of the preceding claims, **characterized by** the improved uncertainty region having an extension which is equal to one half reduced chip period ( $T_{C1}/2$ ).
5. A method according to any one of the preceding claims, **characterized by** repeating said further sub-steps with progressively reduced chip periods and uncertainty regions until a
- 25 desired limitation of the uncertainty region is achieved.
6. A method according to claim 5, **characterized by** the reduced chip period ( $T_{C1}$ ) with respect to a first over-sampling representing an over-sampling by an integer factor of the transmitted direct sequence spread spectrum signal ( $S_{MT}$ ), said
- 30 integer factor being larger than one.

7. A method according to claim 6, **characterized by** the reduced chip period ( $T_{cn}$ ) with respect to any subsequent over-sampling after the first over-sampling representing an integer factor times a foregoing over-sampling, said integer factor being  
5 larger than one.

8. A method according to any one of the preceding claims, **characterized by** the over-sampling involving a linear interpolation between neighboring sampling points.

9. A method according to any one of the claims 1 - 7, **characterized by** the over-sampling involving one or more repetitions of each sampling value.  
10

10. A computer program directly loadable into the internal memory of a computer, comprising software for controlling the steps of any of the claims 1 - 9 when said program is run on the  
15 computer.

11. A computer readable medium, having a program recorded thereon, where the program is to make a computer control the steps of any of the claims 1 - 9.

12. A sensor (100) for determining a distance ( $D_{MT-100}$ ) to a  
20 signal transmitter (MT) based on a direct sequence spread spectrum signal ( $S_{MT}$ ) received from the transmitter (MT), the signal ( $S_{MT}$ ) representing a set of symbols, the sensor (100) comprising:  
a timing unit (220) adapted to determine an estimated transmission delay ( $d$ ) of the received signal ( $S_{MT}$ ) based on a  
25 correlation between at least one representation ( $S_{BB}$ ,  $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) and at least one local spreading sequence ( $S_{PP}$ ,  $S_{bin}$ ), the received direct sequence spread spectrum signal ( $S_{MT}$ ) having a nominal chip period ( $T_C$ ), the timing unit (220) being adapted to produce a chip level synchronization

at least within an uncertainty region of one half nominal chip period ( $T_C/2$ ), and

5 a calculating circuit (230) adapted to calculate the distance ( $D_{MT-100}$ ) on the basis of the transmission delay ( $d$ ) produced by said timing unit (220), **characterized in that** the timing unit (220) comprises:

10 a sampling circuit (221) adapted to over-sample the representation ( $S_{BB}$ ) of the received signal ( $S_{MT}$ ) within the uncertainty region to produce a corresponding over-sampled representation ( $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ), the over-sampling being equivalent to a reduced chip period ( $T_{C1}$ ) which is shorter than the nominal chip period ( $T_C$ ),

15 at least one bank of spreading sequences (223a) adapted to provide a local spreading sequence ( $S_{PP}$ ) containing poly-phased symbol values which are different from the set of symbols represented by the signal ( $S_{MT}$ ), said local spreading sequence ( $S_{PP}$ ) having a nominal chip period which is equivalent to the reduced chip period ( $T_{C1}$ ), and

20 a correlating circuit (222) adapted to cross-correlate the over-sampled representation ( $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) with said local spreading sequence ( $S_{PP}$ ) to obtain an improved uncertainty region being more limited than one half nominal chip period ( $T_C/2$ ).

25 13. A sensor (100) according to claim 12, **characterized in that** the timing unit (220) is adapted to, before cross-correlating the over-sampled representation ( $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) with said local spreading sequence ( $S_{PP}$ ), auto-correlate the representation ( $S_{BB}$ ) of the received signal ( $S_{MT}$ ) with a local copy ( $S_{bin}$ ) of the transmitted spreading sequence from the at  
30 least one bank of spreading sequences (223b) such that a chip level synchronization is obtained within an uncertainty region of one half nominal chip period ( $T_C/2$ ) around an auto-correlation peak.

14. A sensor (100) according to any one of the claims 12 or 13, **characterized in that** it comprises a control circuit (240) adapted to control the timing unit (220) such that for a particular representation ( $S_{BB}$ ,  $\langle S_{BB} \rangle$ ) of the received signal ( $S_{MT}$ ) the at  
5 least one bank of spreading sequences (223a, 223b) provides an appropriate local spreading sequence ( $S_{PP}$ ;  $S_{bin}$ ) to the correlating circuit (222).

15. A system for determining a position ( $P_{xyz}(MT)$ ) of a signal transmitter (MT) transmitting a direct sequence spread spectrum  
10 signal ( $S_{MT}$ ), comprising  
at least three physically separated sensors (100a, 100b, 100c, 100d), each sensor being adapted to receive the signal ( $S_{MT}$ ) transmitted from the signal transmitter (MT), the respective position of each sensor being known, and  
15 a central node (110) adapted to receive distance data ( $D_{MT-100}$ ) from each of the sensors (100a, 100b, 100c, 100d), the distance data ( $D_{MT-100}$ ) representing a respective distance between the transmitter (MT) and the sensor (100a, 100b, 100c, 100d), **characterized in that** each of the sensors (100a, 100b,  
20 100c, 100d) is a sensor (100) according to any one of the claims 12 - 14.